a substrate;

a GaN buffer layer on said substrate;

said channel layer on said GaN buffer layer;

an InGaN spacer layer on said channel layer; and

a doped InGaN donor layer on said InGaN spacer layer

wherein said InGaN spacer layer has a lower InN concentration than said channel layer.

42. The device of claim 7, wherein said AlGaN layer contains an amount of aluminum, Al/(Al+Ga), that does not exceed 0.20.

REMARKS

Amendment of the Specification

The specification has been amended at page 6, second full paragraph, to insert the word "achieve" before "significant," thereby correcting an inadvertent and self-evident error in the text of the application as originally filed.

Cancellation and Addition of Claims Herein

Claims 11-34 have been cancelled herein.

Claims 35-42 have been added herein. Claims 35-41 depend from claim 1, and claim 42 depends from claim 7. No new matter has been added.

The newly added claims are fully supported by and consistent with the originally filed disclosure of the application, as noted below.

Claim 35 recites the device of claim 1, wherein the InGaN alloy contains an amount of indium, In/(In+Ga), that does not exceed 0.20, consistent with the disclosure at page 5, line 24 of "low Al and In content layers" and the disclosure at page 3, line 22 demarcating high content from low content ("[h]igh Al content AlGaN layers ($x > 0.20$)").

Claims 36-38 recite the channel layer as: comprising an InGaN alloy as having a thickness in a range of from about 100 to about 5000 nanometers (claim 36; supported by disclosure at page 6, lines 20-21 of the specification); comprising an InGaN alloy has a thickness in a range of from about 200 to about 2000 nanometers (claim 37; supported by disclosure at page 6, line 22 of the specification); and comprising an InGaN alloy has a thickness in a range of from about 400 to about 1000 nanometers (claim 38; supported by disclosure at page 6, line 23 of the specification).

Claim 39 recites the device of claim 1, comprising:

a substrate;

a GaN buffer layer on said substrate;

said channel layer on said GaN buffer layer;

an AlGaN spacer layer on said channel layer; and

a doped AlGaN donor layer on said AlGaN spacer layer,

as described at page 8, lines 15-21 of the specification.

Claim 40 recites the device of claim 1, comprising:

a substrate;

a GaN buffer layer on said substrate;

said channel layer on said GaN buffer layer;

a GaN spacer layer on said channel layer; and

a doped AlGaN donor layer on said AlGaN spacer layer,

as described at page 9, line 22 to page 10, line 2 of the specification.

Claim 41 recites the device of claim 1, comprising:

a substrate;

a GaN buffer layer on said substrate;

said channel layer on said GaN buffer layer;

an InGaN spacer layer on said channel layer; and

a doped InGaN donor layer on said InGaN spacer layer

wherein said InGaN spacer layer has a lower InN concentration than said channel layer,

as described at page 10, lines 15-22 of the specification.

Claim 42 recites the device of claim 7, wherein the AlGaN layer contains an amount of aluminum, Al/(Al+Ga), that does not exceed 0.20, consistent with the disclosure at page 5, line 24 of "low Al and In content layers" and the disclosure at page 3, line 22 demarcating high content from low content ("[h]igh Al content AlGaN layers ($x > 0.20$)").

With the cancellation of claims 11-34 herein, the addition of the new claims 35-42 does not increase the number of independent or total claims, beyond the numbers for which payment previously has been made. Nonetheless, any additional fee or charge determined to be properly payable in connection with the addition of such claims 35-42 hereby is authorized to be charged to Deposit Account No. 08-3284 of Intellectual Property/Technology Law.

All of the newly added claims 35-42 are of dependent form, and depend directly or indirectly from independent claim 1.

Rejection of Claims in June 5, 2002 Office Action, and Traversal Thereof

In the June 5, 2002 Office Action, objection was made to the amendment filed on March 20, 2002 under 35 U.S.C. §132, and claims 1-9 and 11-34 then pending in the application were rejected on various grounds, including:

- a rejection of claims 13, 16, 24-28 and 32 on 35 U.S.C. §112, first paragraph grounds;
- a rejection of claims 15 and 16 on 35 U.S.C. §112, second paragraph grounds (as well as an ancillary mention of claim 9 as being unclear);
- a rejection of claims 1-2, 14, 21, 29 and 33-34 under 35 U.S.C. §103(a) as unpatentable over Maeda et al. JP11-274474 ("Maeda") in view of Streit et al. U.S. Patent 5,668,387 ("Streit");
- a rejection of claims 3 and 6 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Nagahama et al. U.S. Patent 6,172,382 ("Nagahama");
- a rejection of claims 4 and 5 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Yoshida JP11-261053 ("Yoshida");
- a rejection of claims 7 and 8 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Kawai et al. U.S. Patent 5,929,467 ("Kawai");
- a rejection of claims 9, 15 and 22-23 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Streit as applied to claim 1, further in view of Hoke et al. U.S. Patent 5,448,084 ("Hoke");

- a rejection of claims 11-13 and 30-32 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Streit as applied to claim 1, further in view of Jewell et al. U.S. Patent 5,960,018 ("Jewell"); and
- a rejection of claim 17 under 35 U.S.C. §103(a) as unpatentable over Maeda in view of Streit as applied to claim 1, further in view of O'Loughlin U.S. Patent 5,028,968 ("O'Loughlin").

These rejections are traversed in application to the claims as amended/added herein.

Reconsideration of the patentability of claims 1-9 as amended, and consideration of the patentability of claims 35-42 as herein added, are requested, in light of the ensuing remarks.

Submission of Declaration Under 37 CFR §1.131 of Joan M. Redwing and Edwin L. Piner

Enclosed and submitted herewith is a Declaration Under 37 CFR §1.131 of Joan M. Redwing and Edwin L. Piner, the inventors for the instant application, attesting to facts relating to the conception and practice of the claimed invention.

The Declaration provides evidence of the conception of the claimed invention by the named inventors of the present application at least as early as January, 1997 and diligence from conception to practice of the claimed invention in the performance of the 1998 U.S. Government Contract No. DASG60-98-C-0025 awarded by the U.S. Army Space and Missile Defense Command.

The evidence adduced by the Declaration is presented under the provisions of 37 CFR §1.131 to antedate the Maeda (published October 8, 1999), Yoshida (published September 24, 1999) and Nagahama (effective U.S. filing date January 9, 1998), and Kawai (effective U.S. filing date

December 3, 1997) references, and remove same as applicable references against the instant claims now pending in the application.

The patentable distinction of the now-pending claims 1-9 and 35-42 over the remaining references is discussed in the following section of this Amendment.

Patentable Distinctions of Claims 1-9 and 35-42 Over the Applicable Cited References

With the removal of Maeda, Yoshida, Nagahama and Kawai as applicable references by the Declaration Under 37 CFR §1.131 submitted herewith, the prior rejections, all of which required the primary reference Maeda, are obviated.

Since all of the pending claims 2-9 and 35-42 depend directly or indirectly from independent claim 1, the ensuing discussion is directed to the patentable distinction of claim 1 over the art, since all claims 2-9 and 35-42 dependent thereunder are likewise patentably distinguished.

Streit has been cited as teaching a pseudomorphic HEMT having a channel layer thickness in excess of the critical thickness.

Streit, however, relates to a GaAs-based HEMT device structure, and therefore is inapposite to the instant claimed invention, which requires a "gallium nitride-based HEMT device, comprising an at least partially relaxed channel layer comprising an InGaN alloy" (claim 1).

The instant application at page 2, lines 11-27 describes the fundamental distinction between GaN based materials and GaAs, as follows:

"GaN based materials have physical and electronic properties that make them attractive for high temperature, high power and high frequency devices. Wide bandgap semiconductors (GaN and SiC) have inherently lower thermal carrier generation rates and higher breakdown fields compared to Si and GaAs, as shown in Table 1 below.

Table 1

Properties of candidate materials for high power, high temperature, high frequency electronic devices

I. Material Property	Si	GaAs	4H-SiC	GaN
Bandgap (eV)	1.1	1.4	3.3	3.4
Breakdown field (10^5 V/cm)	2	4	30	30?
Electron mobility (cm^2/Vs)	1400	8500	800	900[a], 2000[b]
Maximum velocity (10^7 cm/s)	1	2	2	3
Thermal conductivity (W/cm K)	1.5	0.5	4.9	1.3

(a) for n = 5E16 cm^{-3}; (b) for an AlGaN/GaN structure"

As is apparent from the foregoing, the device properties of GaN and GaAs are so disparate in relation to one another, having bandgaps, breakdown fields, electron mobilities, maximum velocities, and thermal conductivities of fundamentally different magnitudes, as to rebut the logic of any derivative basis for the applicant's claimed invention in the teachings of Streit.

This fundamental disparity between Streit's teachings and the applicants' claimed invention is further apparent from the channel dimensions taught to be employed by Streit, and the permissible concentration of indium in the channel layer of Streit. See Figure 4 of Streit, and the appertaining disclosure at column 5, lines 52-65 of such reference, particularly the disclosure at lines 59-65, reproduced below for ease of reference:

> **"A series of three data points, generally indicated at 56, shows the degradation of device performance at thicknesses greater than 200 Å for a channel layer having a percentage of indium at 30% or below. Therefore, for a InGaAs channel of this type, dislocations in more than one direction occur at a channel thickness greater than 200 Å, resulting in poor device performance."**

Compare applicant's claims 35-38, reproduced below for ease of reference:

> **35. (new) The device of claim 1, wherein said InGaN alloy contains an amount of indium, In/(In+Ga), that does not exceed 0.20.**
>
> **36. The device of claim 1, wherein the channel layer comprising an InGaN alloy has a thickness in a range of from about 100 to about 5000 nanometers.**
>
> **37. The device of claim 1, wherein the channel layer comprising an InGaN alloy has a thickness in a range of from about 200 to about 2000 nanometers.**
>
> **38. The device of claim 1, wherein the channel layer comprising an InGaN alloy has a thickness in a range of from about 400 to about 1000 nanometers.**

Thus, it is evident that one of ordinary skill in the art would on the basis of fundamental considerations of disparity of materials properties avoid any attempt to apply the GaAs teachings of Streit to a GaN-based HEMT structure. There is accordingly no derivative basis in Streit for the HEMT device structure of applicants' claimed invention.

Further, even if one of ordinary skill were to apply Streit's teachings to a GaN-based HEMT device (despite the absence of any credible basis for such extrapolation in the teachings of Streit), one would be lead by Streit to use high concentrations of indium (> 30%) in the channel layer (as opposed to the low In concentration channel layer (≤ 20%) utilized in the channel layer of applicants' invention as claimed in claim 35), and one would be led by Streit to avoid channel thicknesses greater than 200 Å since this would (by Streit's express teachings) yield "poor device performance" (Streit, column 5, line

65), as opposed to the channel thicknesses employed in applicants' invention as claimed in claims 36-38, summarized below:

Streit channel thickness, Å	**Streit's equivalent channel thickness, in nanometers**	**Applicants' claimed channel thickness, nanometers**
≤ 200 Å	**≤ 20 nm**	**Claim 36 - "about 100 to about 5000 nanometers"**
≤ 200 Å	**≤ 20 nm**	**Claim 37 - "about 200 to about 2000 nanometers"**
≤ 200 Å	**≤ 20 nm**	**Claim 38 - "about 400 to about 1000 nanometers"**

It therefore is evident that the channel thicknesses accommodated by applicants' claimed invention are 1-2 order(s) of magnitude greater than that disclosed by Streit, and more significantly, Streit teaches away from such higher thicknesses of applicants' claimed invention, as associated with "poor device performance" (Streit, column 5, line 65).

The foregoing distinguishing remarks are also apposite to:

Hoke (GaAs devices; thicknesses well below those discussed above - see, for example, Hoke at column 2, lines 47-48 ("100Å is the maximum thickness") and column 6, lines 17-19 ("channel layer of 600Å ... should be possible," a speculative teaching that at best suggests such value as an aspirational upper limit"); and

Jewell (InGaAsN layers; thicknesses of 0.75 to 2.0 times critical thickness in GaAs-based optoelectronic device structures; illustrative CT value of 94Å (column 27, lines 32-33)).

O'Loughlin describes a GaAs HEMT, but there is no disclosure or suggestion therein of any use of an indium-containing layer or material.

In sum, there is no teaching or suggestion in these cited references for applicants' claimed GaN-based HEMT device structure.

Accordingly, claims 1-9 and 35-42 are now in form and condition for allowance.

Request for Extension of the Term for Response

Request hereby is made under the provisions of 37 CFR §1.136 for a one (1) month extension of the term for response set in the June 5, 2002 Office Action, thereby extending the deadline for reply to the Office Action to October 7, 2002 (in consequence of October 5 and October 6 falling on a Saturday and Sunday, respectively).

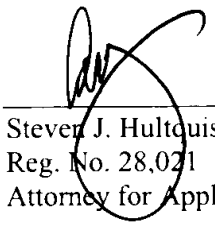
The fee of $110 for such extension is enclosed in a check payable to Commissioner of Patents and Trademarks in such amount. Please charge any deficiency in payment, and credit any excess payment, to Deposit Account No. 08-3284 of Intellectual Property/Technology Law.

CONCLUSION

In view of all the foregoing, formal allowance of claims 1-9 and 35-42 is respectfully requested.

If any issues remain outstanding, the Examiner is requested to contact the undersigned attorney at (919) 419-9350 to discuss their resolution, and to expedite the closure of prosecution on the merits in favor of allowance of the instant application.

Respectfully submitted,



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Appendix A

Marked-up Version of Revised Specification Text

Paragraph at Page 6, lines 10-12

The high electron mobility of InN (4000 cm^2/Vs for n=1E16 cm^{-3}) in relation to GaN permits the use of InGaN alloys in the channel layer of the device to achieve significant improvements in electrical properties and device performance.

Marked-up Version of Revised Claim 9

9. (Twice amended) The device of claim 7, wherein the AlGaN layer [comprising] comprises a dopant [to increase the] providing an increased sheet density [beyond piezo-electrically induced charge] in relation to a corresponding undoped AlGaN layer.